

XI. *A Description of some Fossil Plants, showing Structure, found in the Lower Coal-seams of Lancashire and Yorkshire.* By E. W. BINNEY, F.R.S.

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Introductory Remarks.

ALTHOUGH great attention has been devoted to the collection of the fossil remains of plants with which our coal-fields abound, the specimens are generally in very fragmentary and distorted conditions as they occur imbedded in the rocks in which they are entombed; but when they have been removed, cut into shape, and trimmed, and are seen in cabinets, they are in a far worse condition. This is as to their external forms and characters. When we come to examine their internal structure, and ascertain their true nature, we find still greater difficulties, from the rarity of specimens at the same time displaying both the external form and the internal structure of the original plant. It is often very difficult to decide which is the outside, different parts of the stem dividing and exposing varied surfaces which have been described as distinct genera of plants.

The specimens were collected by myself, and taken out of the seams of coal just as they occurred in the matrix in which they were found imbedded, by my own hands. This enables me to speak with certainty as to the condition and locality in which they were met with.

By the ingenuity of the late Mr. NICOL of Edinburgh, we were furnished with a beautiful method of slicing specimens of fossil-wood so as to examine their internal structure. The late Mr. WITHAM, assisted by Mr. NICOL, first applied this successfully, and his work on the internal structure of fossil vegetables was published in 1833. In describing his specimens, he notices one which he designated *Anabathra pulcherrima*. This did not do much more than afford evidence of the internal vascular cylinder arranged in radiating series, somewhat similar to that which had been found and described by Messrs. LINDLEY and HUTTON as occurring in *Stigmaria ficoides*, in their third volume of the ‘Fossil Flora.’

In 1839 M. ADOLPHE BRONGNIART published his truly valuable memoir, “Observations sur la structure intérieure du *Sigillaria elegans* comparée à celle des *Lepidodendron* et des *Stigmaria* et à celle des végétaux vivants.” His specimen of *Sigillaria elegans* was in very perfect preservation, and showed its external characters and internal structure in every portion except the pith and a broad part of the plant intervening betwixt the internal and external radiating cylinders. Up to this time nothing had been seen at all to be compared to BRONGNIART’S specimen, and no savant could have been better

selected to describe and illustrate it. His memoir will always be considered as one of the most valuable ever contributed on the fossil flora of the Carboniferous period.

In 1849, AUGUST JOSEPH CORDA published his 'Beiträge zur Flora der Vorwelt,' a work of great labour and research. Amongst his numerous specimens, he describes and illustrates one of *Diploxyton cycadoideum*, which, although not to be compared to BRONGNIART'S specimen, still affords us valuable information, confirming some of that author's views rather than affording much more original information. All these last three specimens BRONGNIART, in his 'Tableau de végétaux fossiles considérés sous le point de vue de leur classification botanique et de leur distribution géologique,' published in 1849, classes as *Dicotyledones gymnospermes* under the family of *Sigillariées*; amongst other plants his *Sigillaria elegans*, WITHAM'S *Anabathra*, and CORDA'S *Diploxyton*.

In 1862 the writer published an account of specimens in the 'Quarterly Journal of the Geological Society' of that year, which confirmed the views of the three learned authors above named as to *Sigillaria* and *Diploxyton* being allied plants; he also showed that their supposed pith or central axis was not composed of cellular tissue, but of different sized vessels arranged without order, having their sides barred by transverse striæ like the internal vascular cylinders of *Sigillaria* and *Lepidodendron*. These specimens were in very perfect preservation, and showed the external as well as the internal characters of the plants.

All the above specimens were of comparatively small size, with the exception of that described by CORDA, which, although it showed the external characters in a decorticated state, did not exhibit any outward cylinder of a plant allied to *Sigillaria* with large ribs and deep furrows so commonly met with in our coal-fields, but rather to plants allied to *Sigillaria elegans* and *Lepidodendron*.

In the present communication it is intended to describe some specimens of larger size than those previously alluded to, and to endeavour to show that the *Sigillaria vascularis* gradually passes as it grows older into ribbed and furrowed *Sigillaria*, and that this singular plant not only possessed two woody cylinders, an internal one and an external one, both increasing on their outsides at the same time, but likewise had a central axis composed of hexagonal vessels, arranged without order, having all their sides marked with transverse striæ. Evidence will also be adduced to show that *Sigillaria* dichotomized in its branches something like *Lepidodendron*, and that, as in the latter plant, a *Lepidostrobus* was its fructification. The outer cylinder in large *Sigillaria* was composed of thick-walled quadrangular tubes or utricles arranged in radiating series, and exhibiting every appearance of having been as hard-wooded a tree as *Pinites*, but as yet no disks or striæ have been observed on the walls of the tubes. *Stigmaria* is now so generally considered to be the root of *Sigillaria*, that it is scarcely necessary to bring any further proof of this proposition; but specimens will be described which will prove by similarity of structure that the former is the root of the latter.

The chief specimens described in this memoir are eight in number, and were found

by me in the lower divisions of the Lancashire and Yorkshire coal-measures imbedded in calcareous nodules occurring in seams of coal.

Specimen No. 1, from the first-named district, is from the same locality as the *Trigonocarpon*, described by Dr. J. D. HOOKER, F.R.S., and myself, in a memoir "On the Structure of certain Limestone Nodules enclosed in seams of Bituminous Coal, with a Description of some *Trigonocarpons* contained therein"*, and the other seven specimens are from the same seam of coal in the lower coal-measures as that in which the specimens described in a paper entitled "On some Fossil Plants, showing Structure, from the Lower Coal-measures of Lancashire"†, were met with, but from a different locality.

The position of the seams of coal in which the fossil-woods were found in the carboniferous series will be shown by the following sections of the lower coal-measures.

IN LANCASHIRE.			IN YORKSHIRE.		
	yds.	ft. in.		yds.	ft. in.
Arley or Royley seam	1	1 0	Beeston or Silkstone seam	2	0 0
Strata	69	0 0	Strata	77	0 0
Seam	0	0 3	Royds or Black seam	0	2 10
Strata	57	0 0	Strata	38	0 0
Seam	0	0 6	Better Bed seam	0	1 4
Strata	45	0 0	Strata	51	0 0
Upper flagstone (Upholland)	50	0 0	Upper Flagstone (Elland)	40	0 0
Strata	20	0 0	Strata	40	0 0
Seam (90 yards)	0	0 5	Seam (90 yards)	0	0 6
Strata	20	0 0	Strata	56	0 0
Seam (40 yards)	0	1 6	Seam (40 yards)	0	1 0
Strata	64	0 0	Strata	39	0 0
***Upper Foot seam (Dog Hill)	0	1 2			
Strata	15	0 0			
**Gannister seam	1	0 0	**Halifax Hard seam	0	2 3
Strata	13	0 0	Strata	14	0 0
Lower Foot seam (Quarltun)	0	2 0	Middle seam	0	0 11
Strata	17	0 0	Strata	24	0 0
Bassy seam (New Mills)	0	2 6	Soft seam	0	1 6
Strata	40	0 0	Strata	56	0 0
Seam	0	0 10			
Strata	10	0 0			
Sand or Featheredge seam	0	2 0	Sand seam	0	0 4
Rough Rock of Lancashire (Upper Millstone of Geological Survey)	20	0 0	Upper Millstone of Phillips (Halifax)	36	0 0
Strata (Rochdale or Lower Flags)	120	0 0	Strata (Lower Flagstone)	72	0 0
*Seam	0	0 6	Little seam	0	0 3
Strata	2	0 0			
Seam	0	0 10			
Strata	14	0 0			
Seam	0	1 3			
Upper Millstone of Lancashire.					

In the Lancashire coal-field all the seams of coal, from the forty yards downwards, have at places afforded the *Aviculopecten* and other marine shells in their roofs of black shale, and these latter strata generally contain calcareous nodules. The nodules in the seams of coal commonly known by the name of Bullions have chiefly been found in the beds marked *, **, and *** in Lancashire, whilst in Yorkshire they have as yet been only observed in the Halifax Hard seam marked **.

* Philosophical Transactions, 1855, p. 149.

† Quarterly Journal of the Geological Society of London for May 1862, p. 106.

Description of No. 1 Specimen.

The first specimen intended to be described in this communication is from the thin seam of coal marked * in the lower coal-measures of Lancashire arranged in the vertical section previously given, and is from the same mine from which the specimens described by Dr. HOOKER and myself were obtained. It was found associated with *Calamodendron*, *Halonina*, *Sigillaria*, *Lepidodendron*, *Stigmara*, *Trigonocarpon*, *Lycopodites*, *Lepidostrobus*, *Medullosa*, and other genera of plants not yet determined in the order of relative abundance in which they have been just named.

A portion of a similar specimen of fossil-wood obtained by me from the same locality, on analysis* gave

Carbonate of lime	76·66
Carbonate of magnesia	12·87
Sesquioxide of iron	4·95
Sulphate of iron	0·73
Carbonaceous matter	4·95

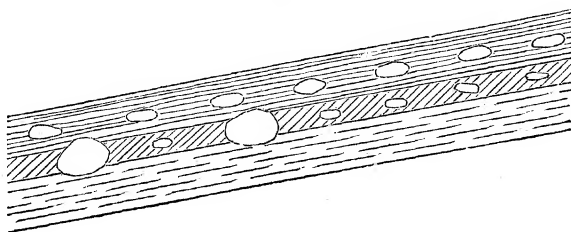
The stratum lying immediately above the seam of coal in which the specimen occurred, generally termed the roof, was composed of black shale containing large calcareous nodules, and for a distance of about 2 feet 6 inches upwards was one entire mass of fossil shells of the genera *Goniatites*, *Orthoceratites*, *Aviculopecten*, and *Posidonia*.

The beds in the vicinity of the coal occurred in the following order, namely,

	yds.	ft.	in.
1. Black shale with nodules containing fossil shells	0	2	6
2. Upper seam of coal enclosing the nodules full of fossil-wood	0	0	6
3. Fire-clay floor full of <i>Stigmara</i>	0	2	0
4. Clay and rock	2	0	0
5. Lower seam of coal	0	0	10
6. Fire-clay full of <i>Stigmara</i> .			

The fossil-wood occurred in circular, lenticular, and elongated and flattened oval-shaped nodules, varying from an inch to a foot in diameter, the round and uncompressed specimens being in general small, whilst the flattened ones were nearly always of a large size. No fossil shells were met with in the nodules found in the coal itself, although, as previously stated, they were very abundant in the nodules found in the roof of the seam, which there rarely contained any remains of plants. The large nodules of 10 to 12 inches in diameter, when they occurred, swelled out the seam of coal both above and below as in the annexed woodcut, fig. 1.

Fig. 1.



* For this analysis I am indebted to the kindness of Mr. HERMANN.

Specimen No. 1 was originally, when first found, 6 inches in length by 7 in breadth, and of an oval form. Its exterior surface was not very well preserved, the outer bark coming off with the matrix of coal in which it was imbedded, but the inner bark showed an irregularly fluted surface marked with fine longitudinal striæ.

In Plate XXX. fig. 1, one half of the specimen is represented. The middle portion of the specimen in transverse section shows a central axis, marked *a*, having its inner portion, *a'*, somewhat compressed, and composed of hexagonal-shaped vessels showing all their sides marked with transverse striæ, arranged without order. Around this axis is a cylinder of hexagonal vessels, *b*, arranged in radiating series of considerably less size than those of the central axis, but having all their sides similarly marked with transverse striæ, and increasing in size as they extend from the centre to the circumference. On the outside of this radiating cylinder is a part of the specimen not showing much structure, but apparently having been once composed of coarse cellular tissue. Beyond this is another zone, for the most part now consisting of mineral matter, chiefly crystallized carbonate of lime, sometimes affording evidence of structure in the form of tubes or elongated utricles arranged in radiating series, and forming an outer cylinder in the plant.

Figs. 2 & 3 show longitudinal and tangential sections of the natural size, taken from the lower and upper portions of fig. 1.

Fig. 4 shows a part of the transverse section, magnified five diameters, where the commencement of the wedge-shaped masses are seen with convex ends adjoining the central axis, and parted by medullary rays or bundles extending from the centre to the circumference, and probably communicating with the leaves on the outside of the plant.

Figs. 5 & 6 show longitudinal and tangential sections of a little more than one half of the specimen, magnified five diameters, the latter displaying the oval-shaped bundles of vessels traversing the internal cylinder of the plant from the centre to the circumference.

This specimen is evidently of the same genus as that described by WITHAM, and obtained by him from Allenbank in Berwickshire, from the mountain-limestone series, and named *Anabathra pulcherrima*, although in a much more perfect state of preservation*. My specimen, however, does not show a pith of cellular tissue, it being rather imperfect in that part; but it distinctly confirms WITHAM's opinion as to the occurrence of medullary rays or bundles dividing the woody cylinder; and it appears to be nearly identical in structure with *Diploxyton cycadoideum* of CORDA†, with which it will be classed.

This specimen is not in so perfect a state of preservation as those fossil-woods intended to be hereinafter described in this communication, especially as regards its central and external parts; but it certainly differs from them in having a larger mass of scalariform

* On the Internal Structure of Fossil Vegetables found in the Carboniferous and Oolitic Districts of Great Britain, by H. T. M. WITHAM, F.G.S. &c. Edinburgh, 1833.

† Beiträge zur Flora der Vorwelt, Taf x.

tissue composing the central axis, and having the inner portions of the wedge-shaped bundles forming the internal radiating cylinder of a convex shape as they approach the central axis, somewhat like those represented by BRONGNIART in his *Sigillaria elegans*, and still more resembling those described by CORDA in *Diploxyylon cycadoideum**; but my specimen shows within those convex bundles a broad zone of scalariform tissue arranged without order and marked with transverse striæ.

It has been assumed, both by CORDA and BRONGNIART, that *Diploxyylon* had a pith composed of cellular tissue, surrounded by a medullary sheath of hexagonal vessels arranged without order, barred on all their sides with transverse striæ. My specimen is evidently more complete in structure than those of the last-named authors, or even that which WITHAM himself described; but although it shows the so-called medullary sheath in a very perfect state, there is nothing to indicate the former existence of a pith of cellular tissue. All the specimens examined by WITHAM, CORDA, and BRONGNIART appear to have had their central axes removed altogether and replaced by mineral matter, or else only showing slight traces of their structure; and these authors appear to have inferred the former existence of a pith of cellular tissue, rather than to have had any direct evidence of it in the specimens of *Anabathra*, *Diploxyylon*, and *Sigillaria* respectively figured by them. Every collector of coal-plants is well aware of the blank space so generally left in the above fossil plants as well as in the roots *Stigmariæ*. It is quite true that a little disarrangement of the scalariform vessels (α') in the specimen is seen; but the part which remains undisturbed shows that the whole of the central axis was formerly composed of hexagonal vessels arranged without order, having all their sides marked with transverse striæ and not of cellular tissue. This view is confirmed by another and more perfect specimen of *Anabathra* in my cabinet, and enables me to speak with positive certainty, and to show that these three plants had a similar structure in the central axes to the specimens of *Sigillaria vascularis* described by me in my paper published in the Quarterly Journal of the Geological Society.

My specimen clearly proves the existence of medullary rays or bundles traversing the internal woody cylinder, which originate on the outside of the central axis; and it appears to me pretty certain that CORDA's specimen of *Diploxyylon cycadoideum*, if tangential sections had been made and carefully examined, would have done the same.

The exterior of the specimen is not in a very complete state of preservation, but it seems to have been covered by irregular ribs and furrows, with slight indications of remains of the cicatrices of leaf-scars. Its marked character, as previously alluded to, is the great space occupied by the central axis. This is of much larger size than in either the *Sigillaria vascularis* or the specimens intended to be next described.

The lunette-shaped ends of the wedge-like bundles of the inner woody cylinder bear some resemblance to the form of the same parts of the *Sigillaria elegans* of BRONGNIART, but much more to those of CORDA's *Diploxyylon cycadoideum*, with which it appears to be identical.

* See M. BRONGNIART's paper on *Sigillaria*, previously quoted.

The lunette-shaped extremities of the inner radiating cylinder of *Diploxyylon cycadoideum*, as well as those in my specimen, remind us of a similar arrangement shown to occur in *Stigmaria* by Dr. HOOKER, in plate 2. fig. 14*; and they appear to differ from those found in *Sigillaria vascularis* in not being divided from the central axis by a distinct line of demarcation, just as the same author's *Stigmaria* fig. 5 differs from fig. 14. The exterior of the inner radiating cylinder of the former plant is more free and open, and not so sharp and compact as that of the latter plant. Indeed, from structure alone, it would appear probable that the first-named *Stigmaria* was the root of *Diploxyylon*, whilst the last one was the root of *Sigillaria vascularis*.

As BRONGNIART has preferred CORDA'S name of *Diploxyylon* to *Anabathra*, and as the former is a more expressive generic term in my opinion, probably it is better to adopt it, and accordingly the specimen has been denominated *Diploxyylon cycadoideum*.

Description of Specimens Nos. 2, 3, 4, 5, 6, 7, & 8.

The second specimen intended to be described in this memoir is from a small seam of coal about 2 feet in thickness in the lower coal-measures, marked ** in the vertical section previously given, and from the same seam that the specimens of *Sigillaria vascularis*, described by me in the paper published in the Quarterly Journal of the Geological Society previously quoted, came from, although from a different locality. This specimen, as well as those numbered respectively 3, 4, 5, 6, & 7, all came from the Halifax Hard seam, the Gannister coal, at South Owsram near Halifax. It was found associated with *Sigillaria*, *Stigmaria*, *Lepidodendron*, *Calamodendron*, *Halonina*, *Diploxyylon*, *Lepidostrobus*, and *Trigonocarpon*, and other fossil plants not well determined in the order of relative abundance in which they have been just named.

A portion of one of the specimens, a large *Sigillaria*, gave, on analysis†,

Sulphates of potash and soda	1·62
Carbonate of lime	45·61
Carbonate of magnesia	26·91
Bisulphide of iron	11·65
Oxides of iron	13·578
Silica	0·23
Moisture	0·402

The stratum found lying immediately above the seam of coal in which the nodules occurred was composed of black shale containing large calcareous concretions, and for about 18 inches was one entire mass of fossil shells of the genera *Aviculopecten*, *Goniatites*, *Orthoceratites*, and *Posidonia*.

* Memoirs of the Geological Survey of Great Britain, vol. ii. part 1.

† For this analysis I am indebted to the kindness of Dr. R. ANGUS SMITH, F.R.S., who had it done in his laboratory by Mr. BROWNING.

The beds occurred in the following (descending) order, namely,

- | | ft. | in. |
|--|-----|-----|
| 1. Black shale full of fossil shells and containing calcareous concretions | 1 | 6 |
| 2. Halifax Hard seam with the nodules containing the fossil plants | 2 | 0 |
| 3. Floor of fire-clay and Gannister, full of <i>Stigmaria ficoides</i> . | | |

The fossil-wood is found in nodules dispersed throughout the coal, some being spherical and others elongated and flattened ovals, varying in size from the bulk of a common pea to 8 and 10 inches in diameter. In some portions of the seam of coal the nodules are so numerous as to render it utterly useless, and they will occur over a space of several acres, and then for the most part disappear and again occur as numerous as ever. For a distance of from twenty-five to thirty miles the nodules occur in this seam of coal in more or less abundance, but always containing the same plants. Fossil shells are rarely met with in the nodules found in the coal, but they occur abundantly in the large calcareous concretions found in the roof of the mine, and are there associated with *Dadoxylon* containing *Sternbergia*-piths, which plant has not yet been noticed in the coal, and *Lepidostrobus*. So far as my experience extends, the nodules in the coal are always found associated with the occurrence of fossil shells in the roof, and may probably be owing to the presence of mineral matter held in solution in water, and precipitated upon or aggregated around certain centres in the mass of the vegetable matter now forming coal before the bituminization of such vegetables took place. No doubt such nodules contain a fair sample of the plants of which the seams of coal in which they are found was formed, and their calcification was most probably chiefly due to the abundance of shells afterwards accumulated in the soft mud now forming the shale overlying the coal.

The specimen illustrated in Plate XXXI. fig. 1, is of an irregular oval shape, 1 foot 3 inches in circumference, 7 inches across its major, and $3\frac{1}{2}$ inches across its minor axis. When first discovered it was 8 inches in length, and only a fragment of a much larger stem. The light-coloured disk in the middle, about an inch in diameter, shows the central axis and the internal radiating cylinder of woody tissue, while the indistinct radiating lines towards the circumference indicate the outer cylinder, formed of thick-walled tubes or utricles of quadrangular form arranged in wedge-shaped masses divided by coarse muriform tissue, increasing in the opposite direction as to their size that the wedge-shaped masses do: all of the natural size.

Fig. 2 shows the outside appearance of the specimen marked with fine longitudinal striæ, irregular ribs and furrows, and some cicatrices of leaf-scars, which would induce most collectors of coal-plants to class it with a decorticated specimen of *Sigillaria*. It most resembles *Sigillaria organum*. The bark of a portion of the specimen remains attached to it in the form of coal, that is united to the matrix of the seam in which the fossil was found imbedded. The reverse side of the specimen does not show the character so distinctly.

Here we have a *Stigmaria*-like woody cylinder, with a central axis composed of barred

vessels arranged without order, found in the inside of a stem of *Sigillaria* in such a position as it existed in the living plant. It is not a solitary instance, but one of more than fifty specimens exhibiting similar characters which have come under my observation.

In Plate XXXII. fig. 1, is represented the light-coloured disk previously alluded to, and shown in Plate XXXI. of the natural size, but here magnified 5 diameters, exhibiting the central axis composed of hexagonal vessels arranged without order, of several sizes, those in the middle being smaller and becoming larger towards the outside, where they come in contact with the internal radiating cylinder *b*, and then again diminishing in size. This latter was no doubt cylindrical, like the stem of the plant, but both parts in the process of petrification have been altered by pressure to their present forms. It consists of a broad cylinder (*b*) of about an inch in diameter, composed of parallel elongated tetragonal or hexagonal tubes of equal diameter throughout for the greater part of their length, obtuse and rounded at either extremity, and everywhere marked with crowded parallel lines which are free or anastomosing all over the surface. The tubes towards the axis are of the smallest diameter; they gradually enlarge towards the circumference, where the largest are situated, though bundles of smaller tubes occasionally occur among the larger. This cylinder, which for convenience may be called the internal woody system of the plant, is divided into elongated wedge-shaped masses, pointed at their posterior or inner extremity, and parted by fine medullary rays of various breadths, some much narrower than the diameter of the tubes, others considerably broader, but none are conspicuous to the naked eye, except towards the outer circumference in some rare instances.

Fig. 2 represents a transverse section of the central axis and the commencement of the internal radiating cylinder, magnified 12 diameters. The hexagonal vessels in the centre and at the circumference, where they come in contact with the internal radiating cylinder, are smaller in size than those seen in the other parts of the axis. The dark line across the axis, as well as the dark space in the centre, both seem to be the result of a disarrangement of the tubes during the process of mineralization, as similar appearances have not been observed in many other specimens examined by me, which in those parts are in a more perfect state of preservation. The dark and sharp line separating the vessels of the central axis from those of the internal radiating cylinder does not permit us to clearly see the origin of the medullary rays or bundles which undoubtedly traverse the latter.

Fig. 3 represents a longitudinal section taken on the right-hand side of the specimen, and extending across the whole of the internal radiating cylinder through the central axis, the intermediate space between the internal radiating cylinder and the outer cylinder, and the external radiating cylinder to the outside of the stem, magnified 4 diameters: *aa* showing the smaller barred vessels of the central axis, having some (*a' a'*) which appear to have been disarranged; *bb* the internal radiating cylinder of larger barred vessels; *c* the space occupied by lax cellular tissue traversed by bundles of vessels; and *d* the external radiating cylinder, consisting of elongated tubes or utricles arranged

in radiating series diverging from certain circular openings, and divided by masses of muriform tissue which contain the medullary rays or bundles.

Fig. 4 is a tangential section of the same parts of the specimen as lastly described, magnified 4 diameters; *b' b'* showing the medullary rays or bundles traversing the inner radiating cylinder, and *d' d'* those traversing the outer radiating cylinder.

Plate XXXIII. fig. 1 is a longitudinal section of a portion of the same specimen, exhibiting the central axis* and the inner radiating cylinder, magnified 15 diameters.

Fig. 2 shows several of the vessels of the central axis as they would be if they were not ground away in the operations of slicing and polishing, magnified 45 times.

Fig. 3 is a tangential section of the inner radiating cylinder, *b* showing the barred vessels, and *b''* the medullary rays or bundles, magnified 15 diameters.

Figs. 4 & 5, longitudinal and tangential sections of the same specimens, showing the structure of the outer radiating cylinder, *d* denoting the tubes or elongated utricles of which it is composed, and *d'* the medullary rays or bundles which traverse it, magnified 10 diameters.

Plate XXXIV. fig. 1 represents a transverse section of a ribbed and furrowed stem (No. 3), displaying similar cicatrices to that of No. 2 given in Plate XXXI., and having a like central axis, as well as like internal and external radiating cylinders and other parts, magnified 2 diameters. It is given for the purpose of more distinctly showing the tubes or elongated utricles, *d*, and the fusiform openings formed of very open muriform tissue, *d'* enclosing the medullary rays or bundles which traverse the external radiating cylinder. This it does in a very marked manner: magnified 20 diameters.

In Plate XXXV. figs. 1, 2 & 3 (Nos. 4, 5 & 6), are shown the exteriors of three central axes separated from large ribbed and furrowed stems, in every respect similar to those described in Plate XXXI. and Plate XXXIV., and such as might easily be taken for small *Calamites*, magnified $2\frac{1}{2}$ diameters. Fig. 4 (No. 7) shows the outside of the internal woody cylinder of a *Stigmaria* with ribbed and furrowed characters, resembling those shown on the outsides of the central axes lastly described, also magnified $2\frac{1}{2}$ diameters.

The first three specimens, Nos. 4, 5 & 6, are from the Halifax Hard seam of coal at South Oram, but No. 7 is from the Wigan Five Feet Mine, a seam in the middle coal-measures.

The tangential sections which show the medullary rays or bundles that traverse the inner and outer radiating cylinders, afford clear evidence of the different appearance of the bundles marked *b''* in Plate XXXIII. fig. 3, from those in Plate XXXIV. fig. 2 marked *d'*.

Specimens Nos. 2 & 3 bear considerable resemblance to the *Sigillaria elegans* of BRONGNIART, with respect to their internal radiating cylinder and the medullary rays or bundles which traverse it, assuming that such vessels come from the outside of the central axis, and not from the exterior of the internal radiating cylinder, as that distin-

* In the Plate the small tubes *a' a''* appear to be divided by septæ. This is certainly the case in one slice, but in another of the same specimen these septæ are not seen, but small barred vessels appear in their places, so the former may probably be due to the direction of the slice being cut along the dark line which traverses the central axis, as shown in Plate XXXII. figs. 1 & 2.

guished savant supposed. Certainly there is no evidence in my specimens to support the latter view. A great many specimens have been broken up and destroyed for the purpose of examining the inner radiating cylinder, and in every case medullary rays or bundles were found traversing it, just as you find in the same part of *Stigmaria*. On the outside of the inner cylinder, at the extreme part of the zone of coarse and lax cellular tissue which bounds it, are some circular openings, from which spring the wedge-shaped masses of quadrangular, tubular, or elongated utricles which form the outer radiating cylinder. The lax cellular tissue has nearly always been displaced and disarranged in the process of mineralization, and sometimes the outer radiating cylinder and the circular orifices connected with it have been pushed towards the inner cylinder. This may have been the case in BRONGNIART'S specimen, and caused him to suppose that the medullary rays or bundles originated only on the outside, and were not joined to those which traversed the inner cylinder. So far as my large specimens show, there were medullary rays which had their origin next the central axis, passed through the inner cylinder, and after traversing the zone of lax cellular tissue outside the latter, apparently communicated with similar rays or bundles of vessels of much larger size, which are always found traversing the outer radiating cylinder, and then went on to the leaves on the outside of the stem.

In BRONGNIART'S specimen the tubes or elongated utricles composing the outer radiating cylinder appear to have been far more delicate in structure than the thick-walled tubes in specimens Nos. 2 & 3*, but probably not more so than might be expected from the difference in size of the plants, my specimens being about twelve times as large as his, and in all probability so much older individuals. The tubes in mine might easily be mistaken for similar tubes in *Pinites* if their size and the thickness of their walls were merely considered, and no notice were taken of the discigerous characters of that genus. In my specimens no disks have as yet been observed on the walls of the tubes, nor have they afforded any evidence of the transverse striæ which characterize the tubes of the central axis and internal radiating cylinder. It is possible that these markings may have once existed on the walls of the tubes, and been afterwards obliterated during the process of mineralization. The thick walls of the tubes in my specimens often exhibit circular dots of a yellow colour, bearing some resemblance to coloured disks. The absence of the disks is the only reason for distinguishing the outer tissue in my specimens from the woody portion of *Pinites*, and this absence of disks is sometimes found to prevail on the walls of the tubes of small specimens of *Dadoxylon*, which are found with piths of *Sternbergia* inside them.

The late Mr. J. E. BOWMAN, F.G.S., in his paper on the Fossil Trees discovered on the line of the Bolton Railway, near Manchester†, and which were in all probability old *Sigillaria*, at considerable length endeavoured to prove that they were hard-wooded solid timber trees, in opposition to the then common opinion that they were soft or

* In the longitudinal section represented in the Plates these tubes are made more delicate than they appear in the specimens.

† Transactions of the Manchester Geological Society, vol. i. p. 112.

hollow stems. In my company that author first saw the trees, and he then observed to me that the roots of those fossil trees clearly indicated by their great size and strength that the trees when living had heavy tops.

In all the numerous specimens of large *Sigillaria* which have come under my observation, the outer radiating cylinder shows more or less evidence of lines of growth, and is generally divided into rectangular masses parted by straight lines of sparry matter, just as a piece of oak taken out of a peat bog and dried does at the present day. This similarity in divisional structure strongly supports the view of the late Mr. BOWMAN as to *Sigillaria* being a hard-wooded tree, which has lately been revived by Dr. DAWSON, F.R.S., in his paper "On the Vegetable Structures of Coal," who says, "I am even inclined to suspect that some of the described specimens of Conifers of the coal may be the woody axes of large *Sigillariae*, or at least approaching quite as nearly to those plants as to modern Conifers"*. All the large specimens of fossil trees found in seams of coal give evidence of having been subject to considerable pressure when in a soft state, and this might also cause the divisional lines above alluded to, without resorting to a process like that which takes place in drying bog oak.

In the specimens Nos. 2 & 3 the outer radiating cylinders are nearly an inch and a half in breadth of thick-walled tubes, or elongated utricles arranged in radiating series, and diverging from a circular opening, while in BRONGNIART'S *Sigillaria elegans* the outer radiating cylinder was not more than $\frac{1}{12}$ th of that breadth. Probably my specimens may not prove to be of the same species as that of the celebrated Autun specimen, still they may be of the same genus, although of considerably greater age. But they have the greatest resemblance to the *Sigillaria vascularis* described by me in a paper read before the Geological Society, and printed in its Journal†. All the specimens described in that communication, as well as those in the present one, were obtained by me from the same seam of coal, but at different places, still the two, namely, the large ribbed and furrowed specimens and the small rhomboidal scarred stems, are always found associated together, and they can be traced gradually passing from one into the other. These facts, when taken in connexion with the similarity of structure in the central axis, the internal radiating cylinder, the space filled with lax cellular tissue between the latter and the outer radiating cylinder diverging from circular openings, clearly prove that the smaller specimen is but the young branch of the older stem, No. 2. It is true that the earlier authors who have written on these plants, would scarcely have admitted a ribbed and furrowed *Sigillaria* to have been so intimately connected with a rhomboidal scarred plant, but it is now generally allowed that such differences in external characters would afford no grounds for ignoring the structural similarity of the specimens. Undoubtedly the small *Sigillaria vascularis* was part of a branching stem; for in my cabinet there is a specimen clearly showing two internal radiating cylinders just at the point where the branches dichotomized, as shown in woodcut (fig. 2), so often met with in *Lepidodendron*.

* Quarterly Journal of the Geological Society, vol. xv. p. 636.

† Quarterly Journal of the Geological Society for May 1862.

Whatever evidence Dr. DAWSON had for supposing a large *Sigillaria* to have been possessed of the obtuse top and the flat main roots, as shown in his restored specimen, figured in vol. xv. of the 'Quarterly Journal of the Geological Society,' it is impossible to say, but certainly in all the numerous specimens which have come under my observation nothing has occurred to warrant me in supposing *Sigillaria* to be such a plant. Everything has led me to believe that the leaves and branches, and probably the fructification of *Sigillaria*, would prove to be very analogous to those of *Lepidodendron*.

Fig. 2.

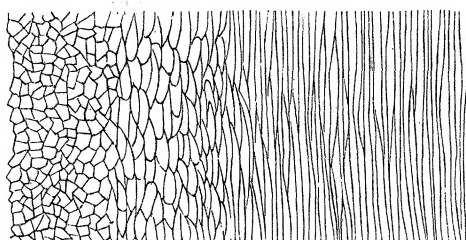


In order to show the identity in structure of specimens 2 & 3 with *Sigillaria vascularis*, previously described by me*, in Plate XXXV. fig. 5 is a specimen of *Sigillaria vascularis* from the same pit and seam of coal as the larger specimen No. 2, showing a transverse section, and fig. 6 exhibiting the external characters of the plant, part being covered with its bark, and part being decorticated, magnified 4 diameters.

On comparing this specimen with those figured in Plates XXXI., XXXII., XXXIII., and XXXIV., the greatest difference is seen in the external characters of the stems; but, as before stated, these can be traced from a regular rhomboidal scar, like that of the *Lepidodendron*, to the irregularly ribbed and furrowed *Sigillaria*. When we examine their internal structure it is found that their central axes are alike. The internal radiating cylinders are the same in both, making allowance for the greater age of the large specimen, each having been undoubtedly exogenous. The space on the outside of the inner radiating cylinder, filled with lax tissue and traversed by medullary bundles, is well marked and defined in the smaller specimen, much more so than in the larger one; but neither show the nature and position of these bundles, which will be noticed more at large in a specimen from a different locality hereinafter described. The outer boundary of this space in the small specimen is marked by a well-defined line of carbonaceous matter. The coarse cellular tissue on the outside of the latter, with the circular openings from which proceed the bundles of vessels traversing the outer zone of tubes or elongated utricles in radiating series, forming the outer cylinder, are the same in both.

The term tubes, or elongated utricles, has been previously employed to denote the structure of the outer cylinder. The inner portion of this zone is made up of what appears to be coarse cellular tissue. This gradually elongates as it proceeds outwards into utricles, which in their turn pass into tubes of a quadrangular form, of which the outer part of the cylinder is composed. The accompanying woodcut (fig. 3) represents a longitudinal section of No. 8, described in Plate XXXV. figs. 5 & 6. From this it is seen that the elongated utricles are more prominent and numerous in the small specimens, whilst in the large specimens, like those in Plates XXXIII. & XXXIV., the tubes are chiefly seen.

Fig. 3.



* Quarterly Journal of the Geological Society for May 1862, p. 106.

The outer cylinder seems to surround the band of lax cellular tissue enveloping the inner cylinder, and appears something in the nature of a pith to it. The inner cylinder no doubt increased on its outside by encroaching on the zone of lax cellular tissue, as may be proved by comparing a young with an old specimen, No. 8 with No. 2.

This outer zone of pseudo-wood increased externally like the inner cylinder, as is evident on comparing the younger with the older plant, the walls of the tubes of the latter being stronger, as might be expected to be the case; and in both we have the singular phenomenon of a tree increasing externally in two different zones at the same time.

As to the internal radiating cylinders described as occurring in the *Diploxyton* and *Sigillaria*, given in this communication, they are evidently like two different *Stigmaria*-cylinders, which afford no structure in their central axes, exactly resembling those figured by Dr. HOOKER in his paper on *Stigmaria ficoides* printed in the 'Memoirs of the Geological Survey of Great Britain'*, in plate 2. figs. 14 & 5. In the latter we have the wedge-form masses of wood of a lunette shape running into the central axis, whilst in the former we have them separated by a sharp and well-defined line from the central axis. The identity of structure between *Sigillaria* and *Diploxyton* and these two *Stigmariæ* is further proved by some specimens which have lately come under my notice.

After the researches of Dr. LINDLEY, Professor GOEPPERT, Mr. PRESTWICH, Dr. HOOKER and others, it really seemed that we had obtained almost a complete knowledge of the internal structure of *Stigmaria*. It is true that only GOEPPERT had seen the isolated bundles in the pith; all the specimens of the other observers having been imperfect in that portion of the plant, and not giving indication of structure there†. In my own researches it has rarely fallen to my lot to meet with a *Stigmaria* showing any structure in the central axis, even where the small stems of *Sigillaria vascularis*, affording all the structure in that part, are in great abundance.

Many years since, after an examination of a great number of specimens of *Stigmaria* in my collection, it occurred to me that an outer radiating cylinder would ultimately be discovered. In my remarks on *Stigmaria*‡ is the following passage:—"That part of *Stigmaria* which intervened between the vascular axis and the bark appears to have consisted of two different kinds of cellular tissue. These, in most cases, have been unfortunately destroyed, so that we cannot positively know their true nature; but they appear to be of different characters, for there generally appears to be a well-marked division. This is often shown in specimens composed of clay ironstone which have not been flattened, and the boundary line is generally about a quarter of an inch from the outside of the specimen. Most probably the outer part of the zone has been composed of stronger tissue than the inner one, as is the case with well-preserved specimens of

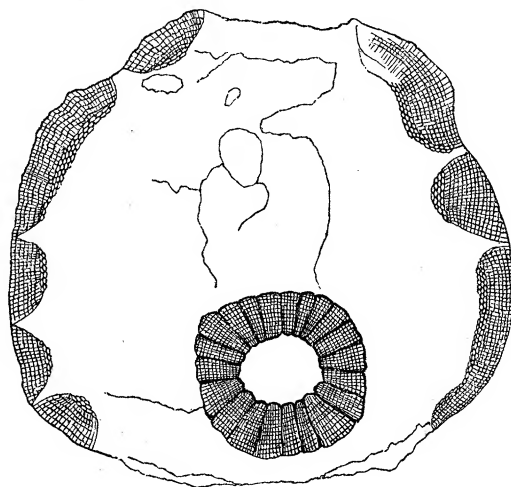
* Memoirs of the Geological Survey of Great Britain, vol. ii. part 1.

† I have written to Professor GOEPPERT for the purpose of obtaining further information as to the pith of this specimen, but I have not been successful in my endeavour.

‡ Quarterly Journal of the Geological Society, vol. iv. part 1. p. 20.

Lepidodendron." It is singular that Drs. LINDLEY and HOOKER, as well as such acute observers as BRONGNIART and GOEPPERT, had not noticed this line of division, but it was no doubt owing to the imperfect specimens which they had examined. After the discovery of the outer radiating cylinder by WITHAM in *Lepidodendron*, and the same arrangement in *Sigillaria* by BRONGNIART, it was to be expected that such outer radiating cylinder would be found to occur in *Stigmaria*, if it were the root of *Sigillaria*. After an inspection of a great number of specimens, the cabinet of Mr. RUSSELL, of Chapel Hall, Airdrie, has afforded me four or five distinct specimens which give clear evidence of the existence of this outer radiating cylinder in *Stigmaria*. They are all in clay ironstone, and have not been much compressed. He has kindly allowed me to slice two of the specimens, which afford decisive evidence of the former existence of both an inner and an outer radiating cylinder. The space on the outside of the inner cylinder does not distinctly show the bundles of vessels communicating with the rootlets, although there is some evidence of their former occurrence. The bell-shaped orifices from which the rootlets spring are well displayed, and the space between them is occupied by wedge-shaped masses of tubes or elongated utricles arranged in radiating series, and not to be distinguished in any way from those shown in Plate XXXV. fig. 5. Indeed the transverse section of the specimen there figured would almost do for a representation of the *Stigmaria* if the latter had the central axis preserved, which it unfortunately has not. There is the same internal radiating cylinder, the same space occupied by lax cellular tissue, which gradually passes into tubes or elongated utricles arranged in radiating series, apparently diverging from circular openings, and parted by large bundles of muriform tissue containing vessels barred on all their sides, extending to the outer bark. The accompanying woodcut (fig. 4) will give a much better idea of its structure than any laboured description.

Fig. 4.



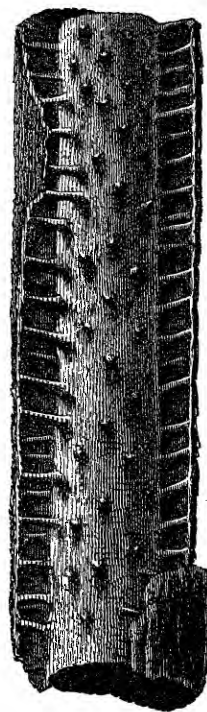
This specimen clearly proves, by the evidence of internal structure alone, that *Stigmaria* is the root of *Sigillaria*, each of them having an inner radiating cylinder com-

posed of barred vessels, a space occupied by lax cellular tissue, and an outer radiating cylinder composed of tubes or elongated utricles.

The broad space intervening between the internal and external radiating cylinders, filled with lax cellular tissue and traversed by medullary bundles communicating with the leaves on the outside of the stem, as shown in the specimens described in this paper, is the only part on which information is required to complete our knowledge of the structure of the stem of *Sigillaria*. Fortunately a small specimen of *Sigillaria vascularis*, kindly presented to me by Mr. WARD, of Longton, a most indefatigable collector, has enabled me to obtain considerable information on this point. This specimen shows the rhomboidal scars on the outside of the stem, the two radiating cylinders and the space between occupied by lax cellular tissue, and traversed by medullary bundles.

The specimen in this woodcut (fig. 5, magnified twice) is of smaller size than any previously described by me, but it is, from both its internal structure and external characters, a small *Sigillaria vascularis* in its young state, when the two radiating cylinders, especially the outer one of the plant, were only slightly developed. The medullary bundles are seen on the outside of the inner radiating cylinder, and pass, inclining upwards at a small angle, from the inner cylinder to nearly the outside of the stem. No trace of the outer cylinder can be seen, so as to enable us to see whether the smaller-sized medullary bundles coming from the inner cylinder join the larger ones in the outer cylinder, described in Plate XXXIV. fig. 2, and there marked *d'*. All the tangential sections show the medullary bundles, both in large and small specimens, to be much greater and stronger in the outer than in the inner radiating cylinder; but no evidence has yet been found of the junction of these medullary bundles to prove that the former run into the latter, or whether the two are distinct. They consist of hexagonal tubes, barred on all their sides, surrounded by muriform tissue, that on the outside of the specimen being of very coarse texture.

Fig. 5.



Up to this time we possess little information as to the organs of fructification belonging to *Sigillaria*. In a paper many years since printed by me*, some *Stigmaria* were described which were found with their insides full of spores, resembling those which were found by Dr. HOOKER in *Lepidodendron*. Similar spores are met with in great abundance in all the seams of splint coal which have been examined by me, the floors of which, it is well known, are one mass of *Stigmaria*. In the strata lying around the large *Sigillaria* found at Dixon Fold, described by the late Mr. J. E. BOWMAN†, that author says, "they (the trees) lie in a stratum of soft shale about four feet thick, among which great quantities of nodules containing cones of *Lepidostrobus*, with pieces of *Stigmaria*, &c., were found."

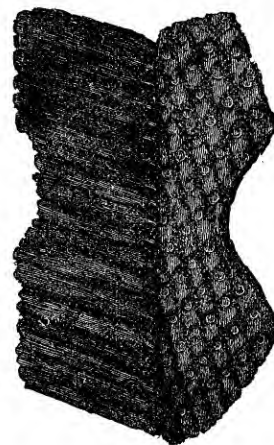
* Quarterly Journal of the Geological Society, vol. vi. p. 17.

† Transactions of the Manchester Geological Society, vol. i. p. 113.

GOLDENBERG gives a description and figures of a cone and spores which he considers to be the fructification of *Sigillaria* *. That author, however, does not give any further evidence of the connexion of the supposed organs of fructification with the stem of *Sigillaria* than had been known in England for years, as previously mentioned. The spores he figures as belonging to *Sigillaria* are exactly the same as those found by me in the inside of *Stigmaria*.

A specimen found in the roof of the same seam of coal in which Nos. 2, 3 & 8 were met with, but at a different place, was given to me by Mr. W. BUTTERWORTH, junior, of Moorside, near Oldham, and enables me to give evidence, equally strong with that adduced by Dr. HOOKER to prove that *Lepidostrobus* was the fruit of *Lepidodendron*, to show that a *Lepidostrobus* was the fruit of *Sigillaria*. Dr. HOOKER, in his excellent paper on this subject †, says, "The doctrine of morphology teaches us that the cone is nothing more than the leafy apex of a branch whose leaves are modified in form, generally to the end that they shall perform the office of protecting organs to reproductive bodies; this is the case of the pine cone, that of the *Lycopodium*, or Club Moss, and many other plants." This specimen is shown in the annexed woodcut (fig. 6), of its natural size, and exhibits sporangia, like those described by Dr. HOOKER in his memoir previously quoted, arranged around the axis of the cone, which does not afford the rhomboidal scars characteristic of the *Lepidodendron*, but presents ribs and furrows, with scars, arranged in quincuncial order, like a small specimen of *Sigillaria organum*. Certainly, if the axis of Dr. HOOKER's cone is to be regarded as nothing more than the continuation of a branch of *Lepidodendron*, the axis of this cone is equally entitled to be classed as the branch of a *Sigillaria*.

Fig. 6.



The organs of fructification, which have been called by geologists fossil cones, and have been classed under the genus *Lepidostrobus*, may not only have belonged to *Lepidodendron* and *Sigillaria*, but it appears nearly certain in my mind that some of them also belonged to *Calamites*. In a paper published many years since, the apparent connexion of *Calamites* and *Sigillaria* was discussed and noticed by the author ‡. Since that time he has collected much further evidence on the structure of *Calamites*, which he proposes at some future time to communicate to the Society in a separate memoir.

In all the large specimens of *Sigillaria vascularis* the outer radiating cylinder has been considerably disarranged by pressure, the original cylindrical form of the plant having been changed into that of an elongated oval. This has been more especially the case with that part of the plant composed of lax and coarse cellular tissue, forming the

* Flora Saraepontana fossilis, Die flora der Vorwelt Saarbrückens, von FR. GOLDENBERG, 11^{tes} Heft, Tafel x. figs. 1 & 2.

† Memoirs of the Geological Survey of Great Britain, vol. ii. part 2, p. 452.

‡ Philosophical Magazine for November 1847, p. 259.

inner portion of the outer cylinder, as well as the thick tubes or elongated utricles, arranged in radiating series, composing the outer part next the bark. Nevertheless in the former there is nearly always some evidence left of circular openings or eyes surrounded by coarse cellular tissue, which gradually assumes a radiating character, and from which the wedge-shaped bundles of tubes or elongated utricles proceed and extend to the outside of the stem. The character of these circular openings, and the wedge-shaped bundles proceeding from them, is well shown in the young specimen of *Sigillaria vascularis*, drawn in Plate XXXIII. fig. 5, and remind us much of what is seen in *Calamodendron*, except that in the latter plant the walls of the tubes exhibit oval openings, sometimes approaching the form of disks, characters which have not as yet, so far as my knowledge extends, been observed in the outer cylinder of *Sigillaria*. In larger and older specimens, as previously stated, the walls of these tubes or elongated utricles of a quadrangular form have become much thicker, and cannot be distinguished from those of *Pinites*, except by the absence of disks.

The outer cylinder, as before noticed, in large specimens always presents divisional lines of a rectangular form, filled by spathose matter, in shape very like those now seen in hard-wooded trees. These appear to me as if made by pressure, but they may have been formed in the process of drying, before the mineralization of the specimen, as previously stated; however, it is still my opinion that these lines originate from pressure rather than desiccation, as there is little evidence yet published of the subaërial decay of the vegetable matter now forming coal, while, on the contrary, nearly every seam of cannel-coal affords abundance of fish remains, and no doubt seams of soft bright coal, if equally favourable for their preservation, would yield them. My cabinet contains specimens from the Oldham coal-field of soft bright coal containing undoubted scales of *Rhizodus*, given to me by Mr. WILD, of Glodwick, and doubtless many more such specimens will be found if carefully looked for.

In the outer portion there is always some appearance of concentric rings, not unlike those seen in our present hard-wooded trees, and which my friend Mr. J. S. DAWES, F.G.S., first noticed in *Calamodendron**. This observation of Mr. DAWES many specimens in my cabinet amply confirm, although they do not bear out that author's statement as to *Calamodendron* having had a pith composed of cellular tissue, as it undoubtedly possessed a central axis composed of large vessels apparently barred on all their sides by transverse striæ, and not to be distinguished from the same part of *S. vascularis*.

Concluding Remarks.

In this memoir the reader will no doubt have seen that it was intended to be more of a descriptive character than an attempt to trace the analogy of the plants whose remains have formed our beds of coal with living vegetables. The subject is surrounded with difficulties, and although the author has been singularly fortunate in meeting with specimens in a good state of preservation, when compared with most hitherto described,

* Quarterly Journal of the Geological Society, vol. vii. p. 198.

still his information is confined to two plants. These, no doubt, have contributed by their remains in a great measure to form the two seams of coal in which they were found, as is evident from the abundance of *Sigillaria*-roots now found in floors of the beds. In addition to this fact, the Halifax Hard or Gannister seam yields the *Sigillaria vascularis* as by far the most common plant found in it.

The large specimens Nos. 2 & 3, now described and figured, some persons may doubt as being the older forms of the *Sigillaria vascularis* described by me some years since in the Geological Society's Journal previously quoted, as well as the medium-sized specimen No. 8 given in Plate XXXV. fig. 5 of this memoir; but the one has been traced gradually passing into the other so as to leave no doubt on this point, and the internal structure is unquestionably the same both in the large and small plants, after making due allowance for the greater age of the former.

The general opinion of botanists and geologists, that *Sigillaria* was a hollow and succulent plant, no doubt arose from the flat specimens generally found compressed into thin plates in indurated clays or shales. The same view was taken with regard to *Calamites*, owing to their being nearly always found in a similar condition; but it is now well known that many specimens of *Calamites* are nothing more than the casts of the central axis of a hard-wooded tree with concentric rings, the whole of which has in most cases disappeared and left no trace of its former existence. Now, although till the discovery of my specimens few, if any, large *Sigillaria* had been found exhibiting structure, it has been shown that the late Mr. BOWMAN, an eminent botanist, many years since pronounced the Dixon Fold fossil trees to be large *Sigillariæ* and hard-wooded dicotyledonous trees with heavy tops, and this he inferred chiefly from the size and form of their roots. Long after the last-named author's death, Dr. DAWSON, in 1859, as previously quoted, was inclined "to suspect that some of the described species of conifers of the coal may be the woody axes of large *Sigillariæ*, or at least of trees approaching quite as nearly to those plants as to modern conifers." Although my specimens do not altogether support Dr. DAWSON's views as to the woody axis he no doubt refers to, namely, the internal radiating cylinder and not the outward one, which he terms a very thick cellular inner bark, his opinion is entitled to considerable weight as to *Sigillariæ* being hard-wooded trees, he having paid great attention to the different structures found in the charcoal now met with in our coals, the floors of which so constantly testify to the presence of *Sigillaria* in the form of roots, and the great part it contributed to their formation. The size of the external cylinder of this plant, when compared with its internal one, is so much greater, that by far the larger portion of the coal must have been derived from the former. It is this part of the fossil tree that so generally divides into rectangular masses, and not the small internal cylinder evidently alluded to by Dr. DAWSON, as any person who has examined many large specimens will well know.

Specimen No. 2 probably may not be considered as so marked an example of the genus *Sigillaria*, owing to the small size and indistinctness of the cicatrices left by the

leaves, which are not so well shown in the Plate as they are generally found on specimens of *Sigillaria organum*. No doubt it cannot be regarded as a good example of the species *organum*, but from the ribs, furrows, and scars on its outside no one will question its being a *Sigillaria*, even if its internal structure did not prove its relationship to *Sigillaria elegans*.

In all my investigations as to the origin of coal, the marine character of the water in which the plants that formed it by their decomposition grew, becomes to my mind more evident. It is now well known to all parties conversant with coal-mining, that in most deep mines where the surface water cannot get down the water found in the coal is quite salt, and contains iodine, bromine, and the usual constituents of sea-water. Any person carefully examining each of the seams of coal in which the fossil woods described in this memoir were found, placed as they are upon an under clay full of *Sigillaria*-roots with their radicles traversing it in every direction, will be convinced that the plants which formed the coal grew on the spot where it is now met with, and were not drifted there, while the presence of such a mass of marine shells as is found in the roof of each seam evidently where they lived and died, equally proves the salt nature of the water.

Little evidence is to be obtained of the character of the dry land of the Carboniferous epoch except what is afforded by a few sun cracks on some of the rocks, but from the shallow seas more resembling marine swamps than the oceans of the present day, it was probably little above the surface of the water. Shallow seas and low lands would of course greatly influence the climate of the period. The strata found in the vicinity of seams of coal, with some few exceptions, show that they were deposited from water during periods of great tranquillity, and the vast range over the old and new worlds of the genus *Sigillaria* found in all their true coal-fields, indicates a uniformity of conditions of which we have now no parallel, and areas of such immense extent as is only equalled by some of our present oceans.

In the Lancashire coal-field, probably one of the best developed in Great Britain, from the bottom to the top there are about 120 different seams of coal, great and small. These indicate 120 periods of rest or repose of the earth's crust, when a primeval forest reared its top above the waters until the vegetable matter now forming each bed of coal was grown and deposited*. Then such forest was submerged and buried under mud and sand now found as shale and sandstone rocks. The hollow caused by such subsidence was silted up until it was again covered by shallow water. Then, again, a fresh crop of vegetation flourished so as to form another bed of coal. For 120 different times did this successive growth of vegetable matter, submergence and silting up go on. In some instances whole forests of *Sigillaria*, standing upright in fine shale, on the top of the seams of coal are met with, thus clearly showing that they were submerged quietly and slowly, whilst at other times the prostrate stems now found lying in sandstone roofs

* Although upright *Sigillariae* are generally found in the roof of a seam of coal, they are also met with in fine-grained shales, midway between seams, less frequently in coal floors, and more rarely still in the seams of coal themselves.—Transactions of the Manchester Literary and Philosophical Society, vol. viii. 2nd series, p. 176.

show that the submergence was rapid, causing strong currents that tore up and drifted the trees. Every one of the floors of these coal-seams is full of the roots of *Sigillaria*; so with the stems of these trees in the roof, the vegetable matter in the seam of coal, and the roots in the floor, there can scarcely be a doubt as to the remains of the vegetables now composing coal having grown on the spots where it is now found, and that *Stigmaria* was the characteristic root of the plants which for the most part produced coal.

The above conditions of the growth of vegetables in shallow seas very different to any state of things now existing, would require a plant suited to them and very different from any now living. After a careful investigation of the structure of *Sigillaria elegans*, BRONGNIART came to this conclusion: "Tous ces motifs doivent nous porter à conclure que les *Sigillaria* et les *Stigmaria* constituaient une famille spéciale entièrement détruite, appartenant probablement à la grande division des Dicotylédones gymnospermes, mais dont nous ne connaissons encore ni les feuilles ni les fruits."

If we take particular parts of *Sigillaria vascularis*, as before described, we can trace resemblances to some living plants. The central axis when taken by itself might appear to connect the plant with ferns, as it certainly bears some resemblance to the root of *Aspidium exaltatum*, as figured by BRONGNIART in plate 8, figs. 10 & 11*. The internal radiating cylinder is somewhat like similar cylinders in *Echinocactus* and *Melocactus*, as figured by the same author.

The vessels with barred and dotted sides in some respects resemble those of *Zamia integrifolia*, also noticed by BRONGNIART, and the outer radiating cylinder in the thickness of the walls of its tubes, or elongated utricles, and their arrangement, points to conifers. Although *Sigillaria* has resemblance in some of its parts to such widely different living plants, there can scarcely be a doubt in the mind of any one who has had the advantage of examining the fossil plant with its far extending roots and long radicles, but that it had an aquatic *habitat*. It attained a large size, as upright specimens have been traced by me nearly 60 feet in height without showing much diminution in size, and the bases of others have come under my observation which have measured over 7 feet in diameter.

DESCRIPTION OF THE PLATES.

PLATE XXX.

Diploxyton cycadoideum.

Fig. 1. Specimen (No. 1) of one-half of a stem of *Diploxyton cycadoideum* in a calcified state, found in the lower coal-measures of Lancashire, in the middle of a seam of coal, showing a transverse section: natural size.

* Observations sur la structure intérieure du *Sigillaria elegans*, p. 447.

Fig. 2. A longitudinal section of the same specimen taken across the minor axis from *d* to *d* in fig. 1: natural size.

Fig. 3. A tangential section of the same specimen taken across the upper part: natural size.

Note.—The same letters indicate the same parts in this and the preceding figures, and also in the subsequent ones.

a a. The middle part, showing the central axis or pith composed of large hexagonal vessels, having all their sides barred by transverse striæ.

a' a'. The smaller hexagonal vessels in the central axis or pith found sometimes interspersed amongst the larger ones, and divided by horizontal septæ.

a'' a''. Small vessels of very delicate elongated tissue found mixed with the other vessels in the axis or pith.

b b. The vascular internal cylinder, in wedge-shaped bundles and radiating series, composed of hexagonal vessels, barred on all their sides by transverse striæ, and divided by medullary rays or bundles, *b'' b''*.

b' b'. Portions of the same cylinder disarranged or destroyed.

b'' b''. Medullary rays or bundles passing through the internal cylinder, and extending to the outside of the stem.

c c. Space on the outside of the internal cylinder, composed of lax cellular tissue, and traversed by vascular bundles frequently disarranged or destroyed, and replaced by mineral matter.

d d. Outer cylinder of tubes or elongated utricles in wedge-shaped bundles, and radiating series of quadrangular form, divided by wide openings filled with coarse muriform tissue, which enclose medullary rays or bundles of an oval or circular form leading to the leaves.

d' d'. Medullary rays or bundles of barred vessels traversing the coarse muriform tissue.

d'' d''. Elongated tissue divided by horizontal septæ (muriform tissue) surrounding the medullary rays or bundles.

Fig. 4. A transverse section of a portion of the same specimen taken across the minor axis, showing the whole of the central axis or pith, one side of the inner radiating cylinder, and the space between the latter and the outside of the stem: magnified 5 diameters.

Fig. 5. A longitudinal section of the same specimen, showing the same parts of the stem as are named in the last figure, magnified 5 diameters.

Fig. 6. A tangential section of the same specimen (upper part), magnified 5 diameters.

PLATE XXXI.

Sigillaria vascularis.

- Fig. 1 (No. 2). Specimen of a stem of *Sigillaria vascularis* in a calcified state, found in the lower coal-measures of the West Riding of the County of York, at North Oworm near Halifax, in the middle of the Hard bed of coal, showing a front view of the upper part, containing the central axis, internal vascular cylinder, space on the outside of the latter composed of coarse cellular tissue, and external radiating cylinder: natural size.
- Fig. 2. Side view of the same specimen, which not only shows the upper part of the specimen like fig. 1, with the central axis, internal radiating cylinder, intervening space of lax cellular tissue, and external radiating cylinder, but a side view of the decorticated portion of the stem with irregular ribs and furrows, on the former of which are traces of the cicatrices left by the leaves of the plant: natural size.

PLATE XXXII.

Sigillaria vascularis.

- Fig. 1 shows a transverse section of the central axis and internal radiating cylinder of the same specimen, magnified 5 diameters.
- Fig. 2. A part of the same specimen, *a* denoting the central axis, and *b* the internal radiating cylinder: magnified 12 diameters.
- Fig. 3. A longitudinal section of the same specimen, commencing on the outside of the internal radiating cylinder passing through the central axis, the other portion of the internal radiating cylinder, the part composed of coarse cellular tissue generally disarranged adjoining to it, and the external radiating cylinder to the outside of the specimen: magnified 4 diameters.
- a a.* Parts of the central axis composed of hexagonal vessels arranged without order, having all their sides marked by transverse striæ.
- b b* Parts of the internal cylinder, composed of hexagonal vessels in wedge-shaped bundles, and radiating series marked on all their sides by transverse striæ parted by medullary rays or vascular bundles communicating from the outside of the central axis to the exterior of the cylinder, and probably extending on to the leaves.
- c c.* Parts of the coarse cellular tissue, generally a good deal disarranged, traversed by large vascular bundles, most probably connected with the medullary rays or vascular bundles of the internal cylinder, and communicating with the leaves.

d d. Parts of the external cylinder, composed of tubes or elongated utricles of a quadrangular form arranged in radiating series, and parted by large vascular bundles surrounded by coarse muriform tissue.

Fig. 4. A tangential section of a portion of the same specimen, magnified 4 diameters.

b. Parts of the internal cylinder, showing a section of the medullary rays or vascular bundles, *b''*.

c. Portions of the coarse cellular tissue, generally a good deal disarranged, traversed by large vascular bundles, most probably connected with the medullary rays or vascular bundles of the internal cylinder, and communicating with the leaves.

d d. Parts of the external cylinder, composed of tubes or elongated utricles of a quadrangular form arranged in radiating series, and parted by large vascular bundles surrounded by coarse muriform tissue.

Fig. 4. A tangential section of a portion of the same specimen, magnified 4 diameters.

b b. Parts of the internal cylinder, showing a section of the medullary rays or vascular bundles, *b''*.

c c. Parts of the coarse cellular tissue somewhat disarranged, but showing some structure, and traversed by vascular bundles.

d d. Parts of the external radiating cylinder, showing the large oval bundles of vascular tissue (*d'*) surrounded by coarse muriform tissue.

PLATE XXXIII.

Sigillaria vascularis.

Fig. 1 shows a longitudinal section of a portion of the same specimen, exhibiting the central axis composed of barred vessels, *a a*, parted by smaller vessels divided by horizontal septæ, *a'*, as well as portions of the internal cylinder composed of barred vessels, *b b*: magnified 15 diameters.

Fig. 2 represents two of the barred vessels of the central axis as they would appear if not ground away in the slicing and polishing, magnified 45 times.

Fig. 3. A tangential section of a portion of the same specimen across a part of the internal cylinder, showing the medullary rays or bundles (*b''*) traversing the cylinder *b*: magnified 15 diameters.

Fig. 4. A longitudinal section of a portion of the external cylinder *d*, composed of tubes or elongated utricles arranged in radiating series, magnified 10 diameters.

Fig. 5. A tangential section of a portion of the external cylinder, showing the large vascular bundles of an oval shape, *d'*, surrounded by coarse muriform tissue which traverse it: magnified 10 diameters.

PLATE XXXIV.

Sigillaria vascularis.

Fig. 1. Specimen (No. 3) of a stem of *Sigillaria vascularis* in a calcified state, found also in the lower coal-measures of North Oworm in the middle of the Hard bed of coal, in company with the last specimen described, showing a portion of the central axis divided and partly disarranged, portions of the internal cylinder composed of hexagonal vessels having all their sides marked with transverse striæ, arranged in radiating series parted by medullary rays or vascular bundles; also a part of the space on the outside of the internal cylinder, composed of coarse cellular tissue, and parts of the external cylinder, composed of tubes or elongated utricles arranged in radiating series, and parted by large vascular bundles surrounded by coarse muriform tissue communicating with the leaves.

The outside of the specimen presented the same kind of ribs and furrows, with indistinct traces of cicatrices, as the specimen No. 2, described in Plates XXXI., XXXII., and XXXIII. It is given chiefly for the purpose of showing the tubes or elongated utricles of the external cylinder, traversed by the large vascular bundles of an oval form, surrounded by coarse muriform tissue which are much more distinctly represented than in the first-named specimen No. 2: magnified 2 diameters.

Fig. 2. A tangential section of the same specimen, showing a portion of the outer cylinder, composed of tubes or elongated utricles, d , traversed by large vascular bundles of the shape of a double cone, composed of very large horizontally-divided tissue, d' , and more finely divided tissue, d'' d''' , and having an oval-shaped vascular bundle in the middle, most probably communicating with the cicatrices to which the leaves were attached on the outside of the plant: magnified 20 diameters.

Fig. 3. A longitudinal section of the same specimen, showing a portion of the outer cylinder, composed of tubes or elongated utricles, d , arranged in radiating series, as well as a portion of a vascular bundle with the fine tissue divided by horizontal partitions, d'' : magnified 20 diameters.

PLATE XXXV.

Sigillaria vascularis.

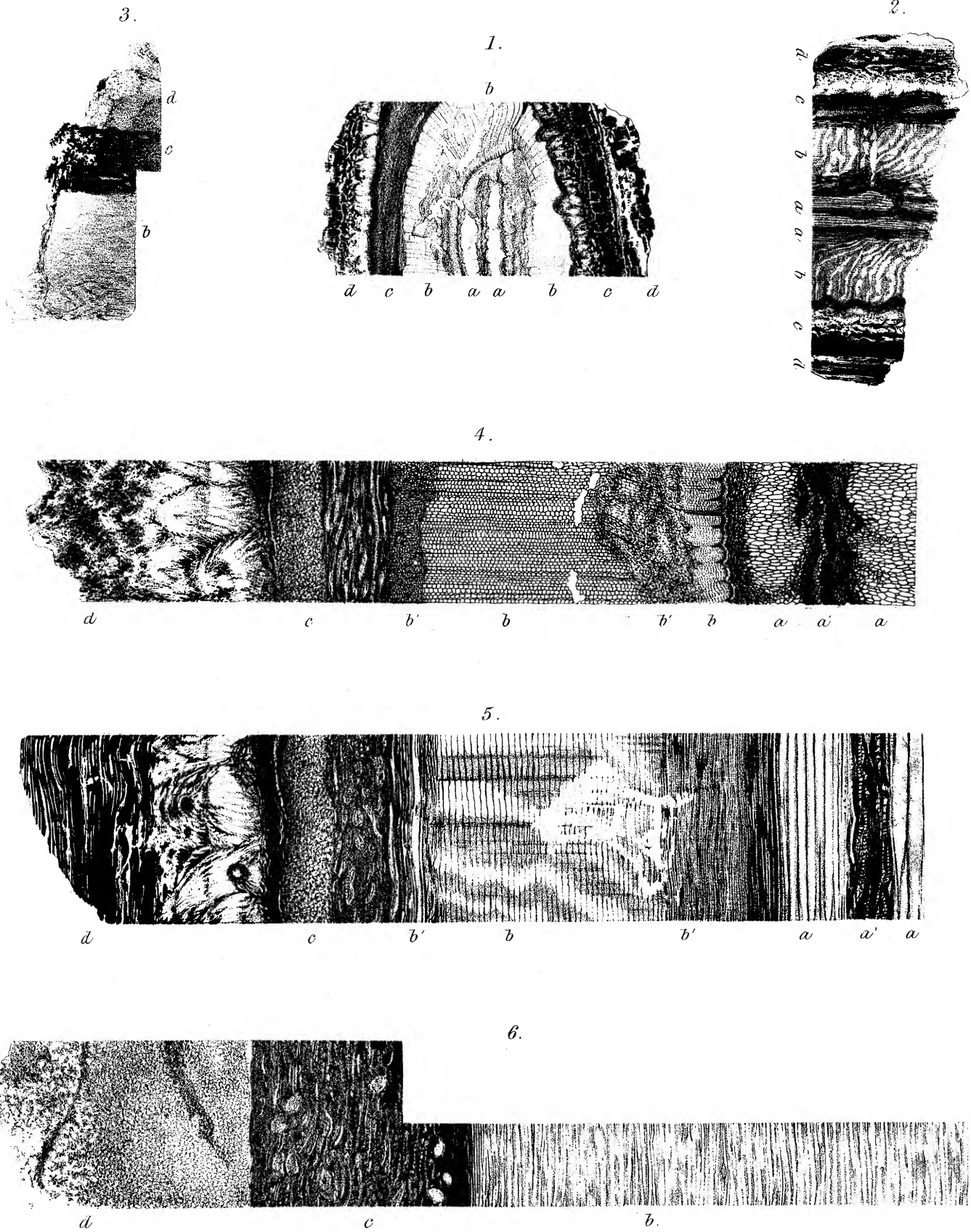
Figs. 1, 2, & 3 (Nos. 4, 5, & 6) represent the external appearance of the central axes of three different specimens of *Sigillaria vascularis*, found in the middle of the Hard seam of coal in company with the specimens Nos. 2 & 3 described in Plates XXXI., XXXII., XXXIII., and XXXIV. They were enclosed in three stems, exactly resembling those specimens in external characters and

internal structure in every respect. The horizontal division in fig. 1 may probably owe its origin to a fissure in the stone rather than a division such as is usually seen in a *Calamites*, but the outside longitudinal striæ in all the specimens remind us of that fossil plant, while the vascular bundles of the central axis of these specimens bear considerable resemblance to some of the species of *Medullosa*: magnified $2\frac{1}{2}$ diameters.

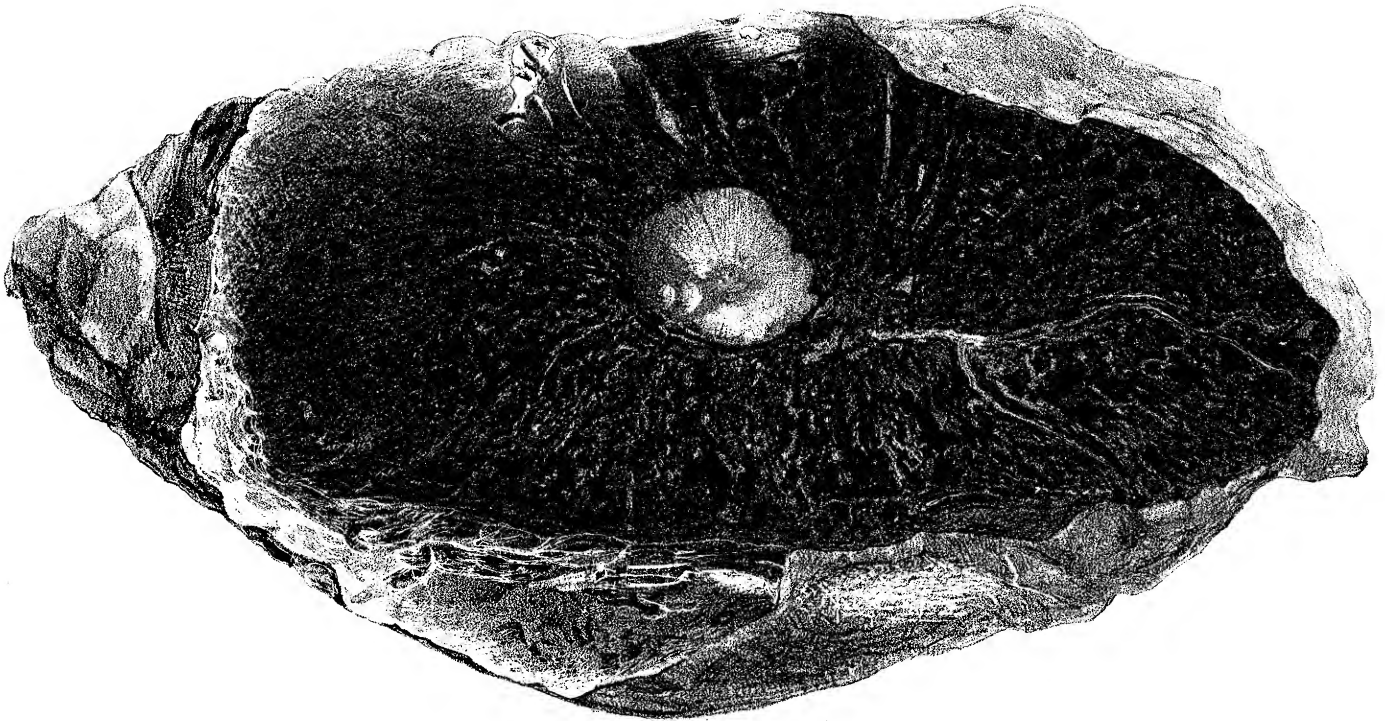
Fig. 4 (No. 7) represents the outside of the inner radiating cylinder of *Stigmarioficoides* arranged in wedge-shaped bundles, showing the finely marked longitudinal striæ with which it was furnished, but not affording any evidence of structure in the central axis: magnified $2\frac{1}{2}$ diameters. This specimen is from the Wigan Five Feet seam of coal of the Ince Hall Coal and Cannel Company, in the middle division of the Lancashire coal-measures, and is the only specimen which has come under my notice which shows the outside of the inner radiating cylinder: magnified $2\frac{1}{2}$ diameters.

Fig. 5 (No. 8) represents a transverse section of a small specimen of *Sigillaria vascularis*, found also in the lower coal-measures of North Oram, in the middle of the Hard bed of coal. It is in a more perfect condition, as a whole, than any of the other specimens described in this paper, and appears to be a younger individual of the same genus and species as the larger and more imperfect ones, Nos. 2 & 3, figured in Plates XXXI., XXXII., XXXIII., and XXXIV., associated with which it was found. It shows the central axis, composed of hexagonal vessels arranged without order, and having all their sides marked with horizontal striæ, the internal cylinder of hexagonal vessels arranged in radiating series, and having all their sides marked with transverse striæ and parted by medullary rays or vascular bundles, the space outside that cylinder occupied by lax cellular tissue traversed by vascular bundles, sections of some of which are seen as circular openings, a dark line bounding it, the zone of coarse cellular tissue outside that last named containing circular and oval openings, and passing into tubes or elongated utricles arranged in radiating series, and divided by large medullary rays or vascular bundles, forming the external cylinder, and an outer bark enveloping the plant: magnified 4 diameters.

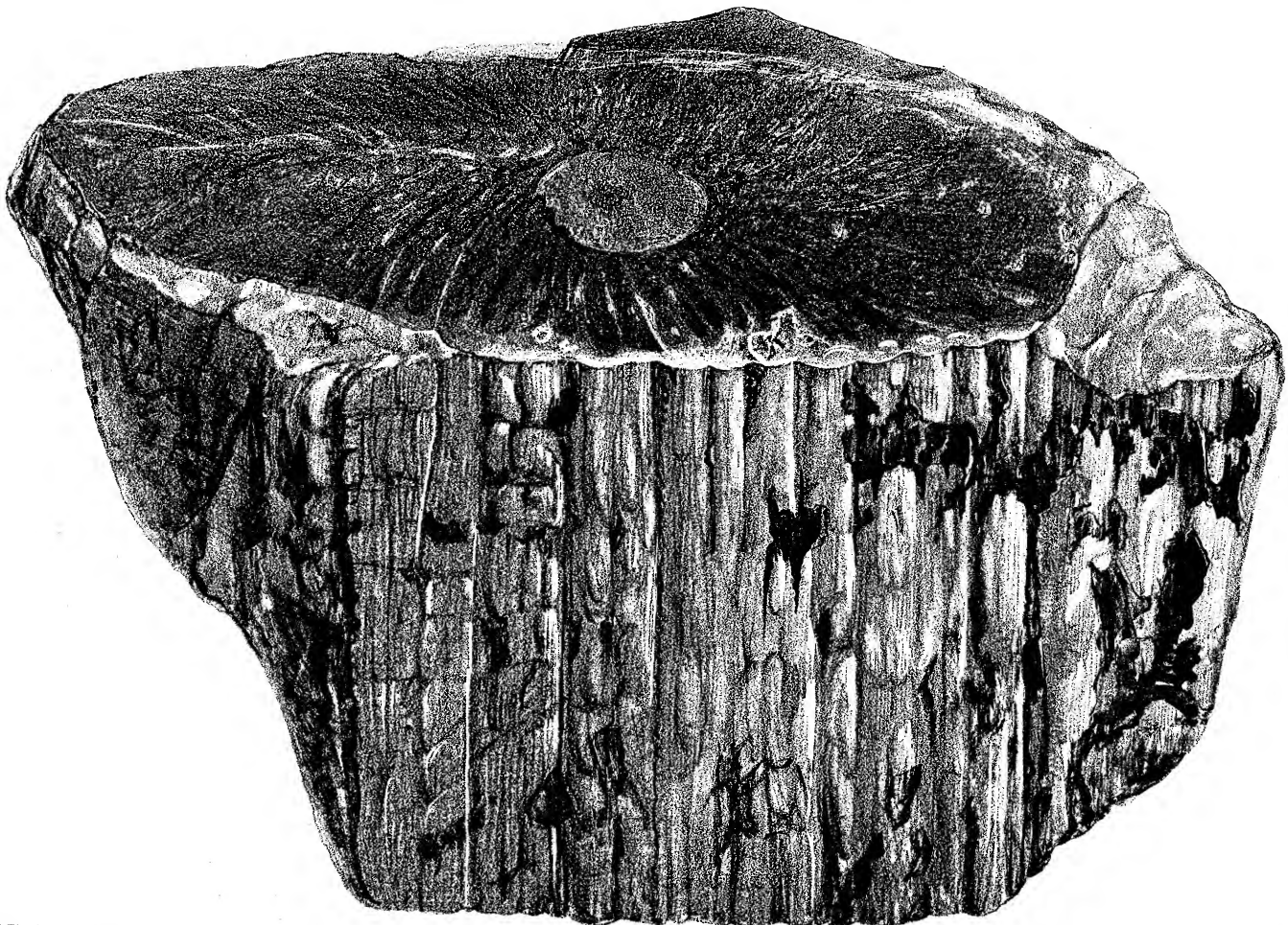
Fig. 6 (No. 8) represents the outside view of the same specimen partly covered by a thick carbonaceous coating, probably representing the outer bark and partly decorticated, displaying rhomboidal scars, having a rib running through their major axis, in the middle of which is a cicatrix of a circular form left by the leaf. The scars and cicatrices upon them were arranged in quincuncial order. The specimen appears to be older than those described by me in the Geological Journal previously alluded to, and younger than specimens 2 & 3 of this paper: magnified $2\frac{1}{2}$ diameters.



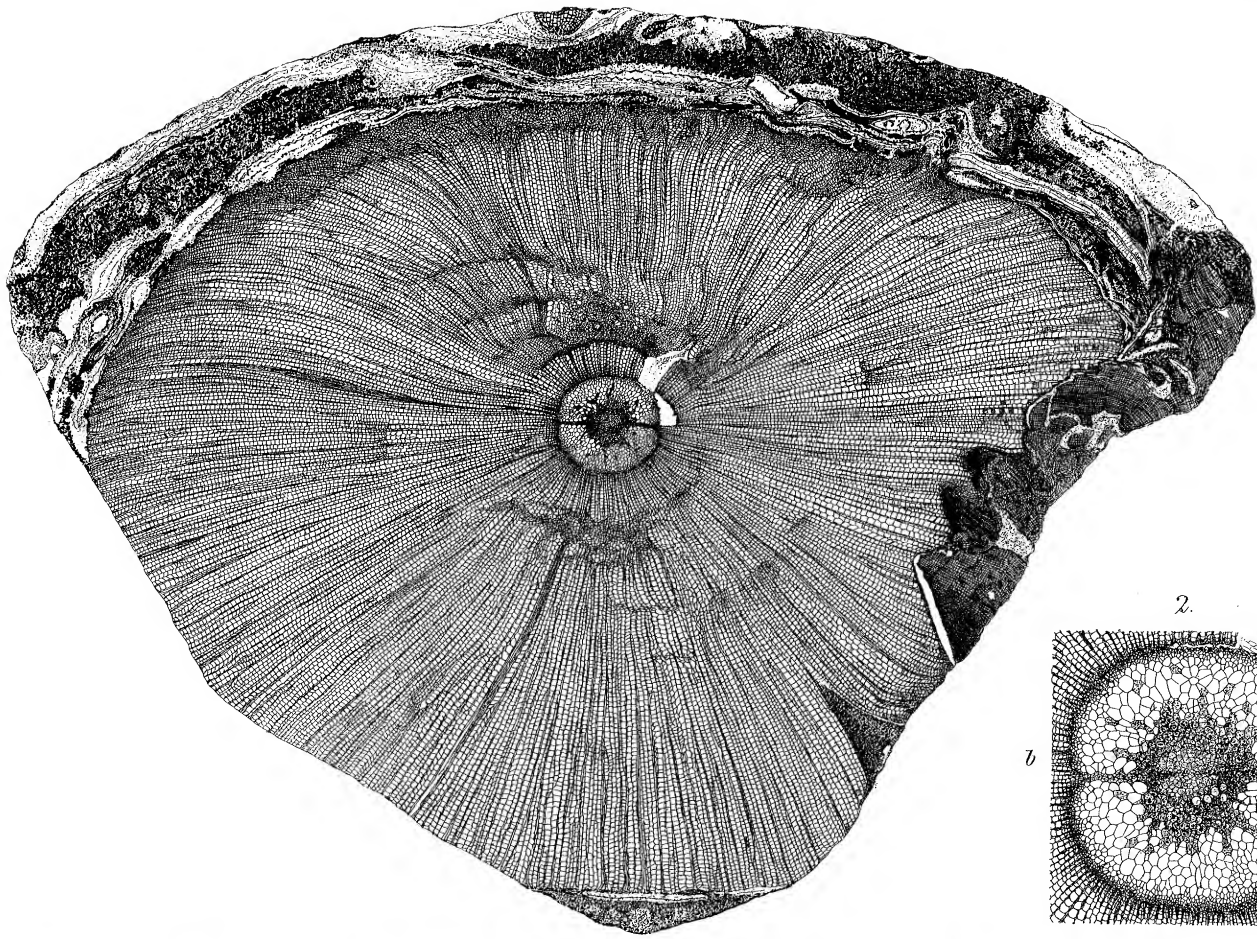
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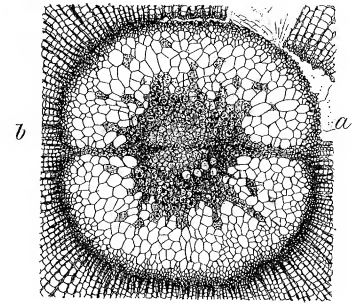
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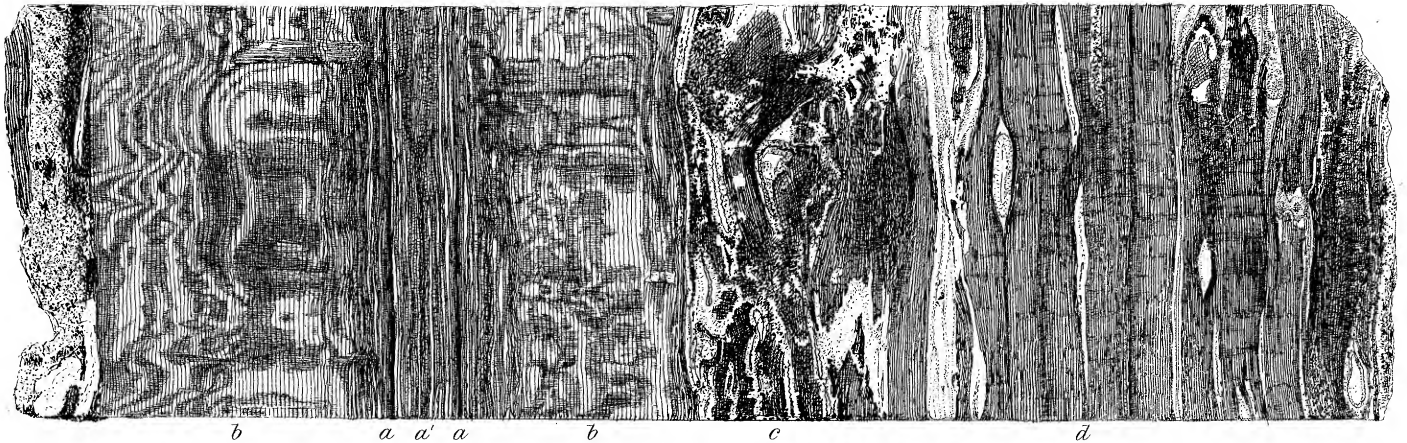
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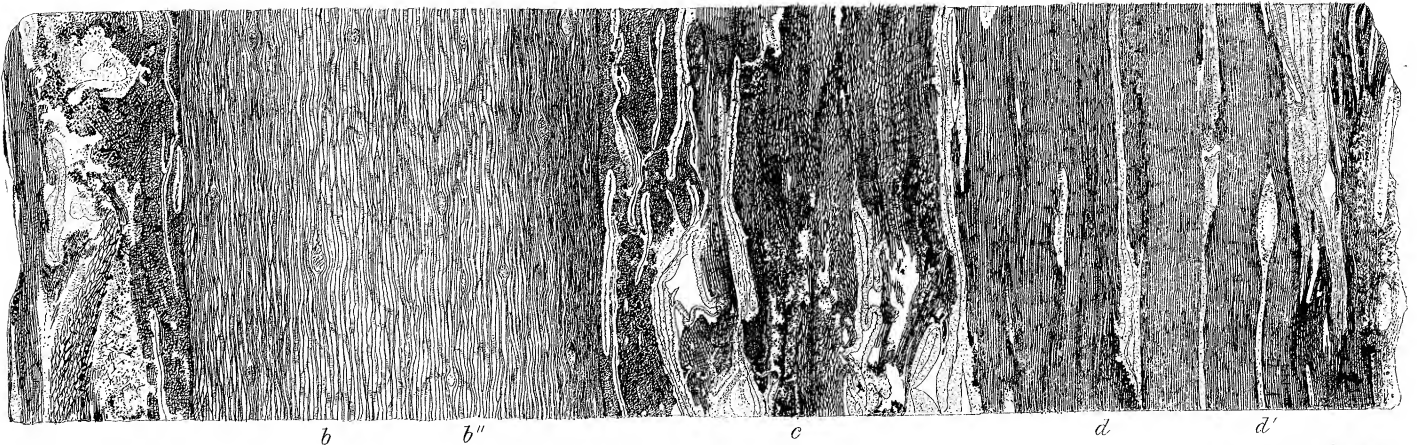
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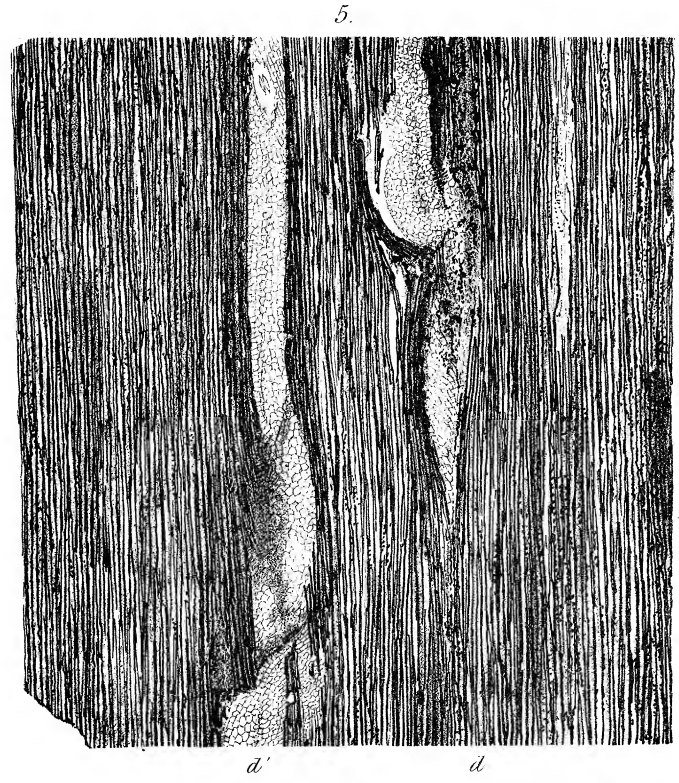
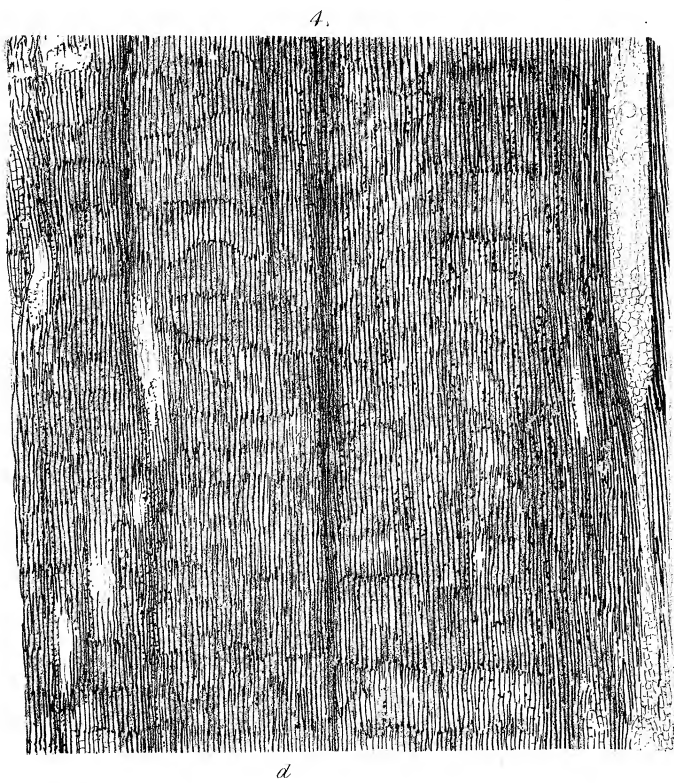
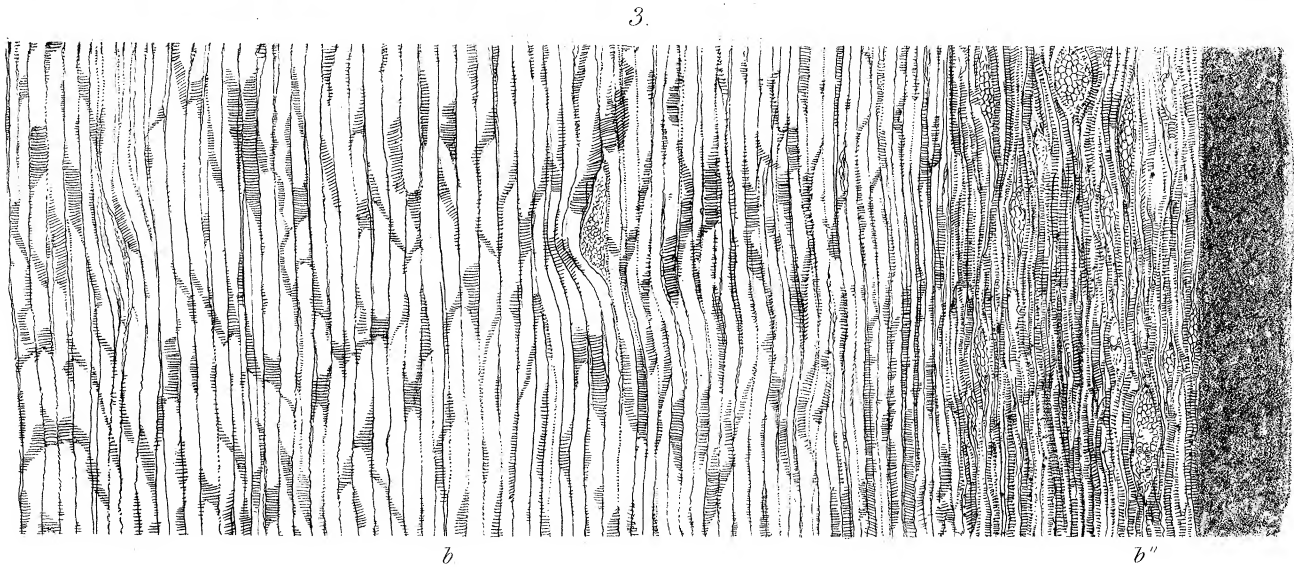
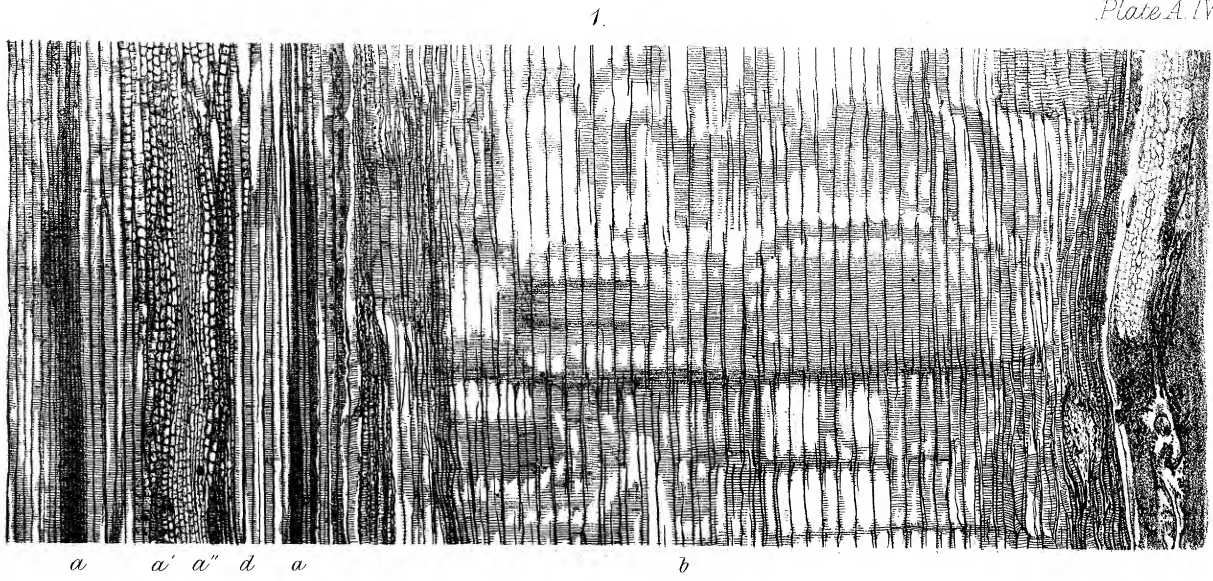
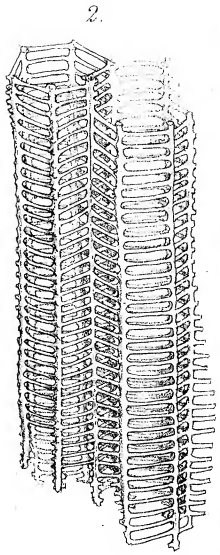


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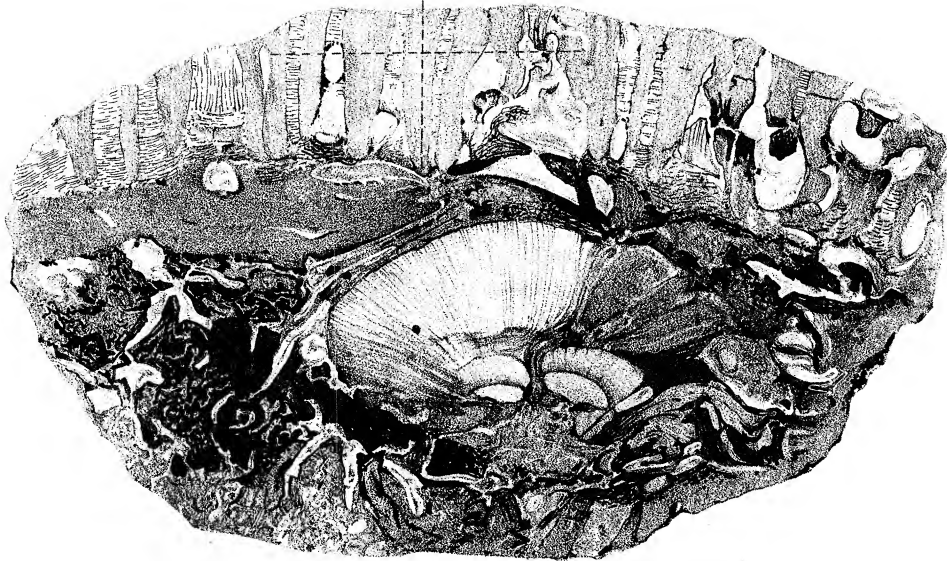


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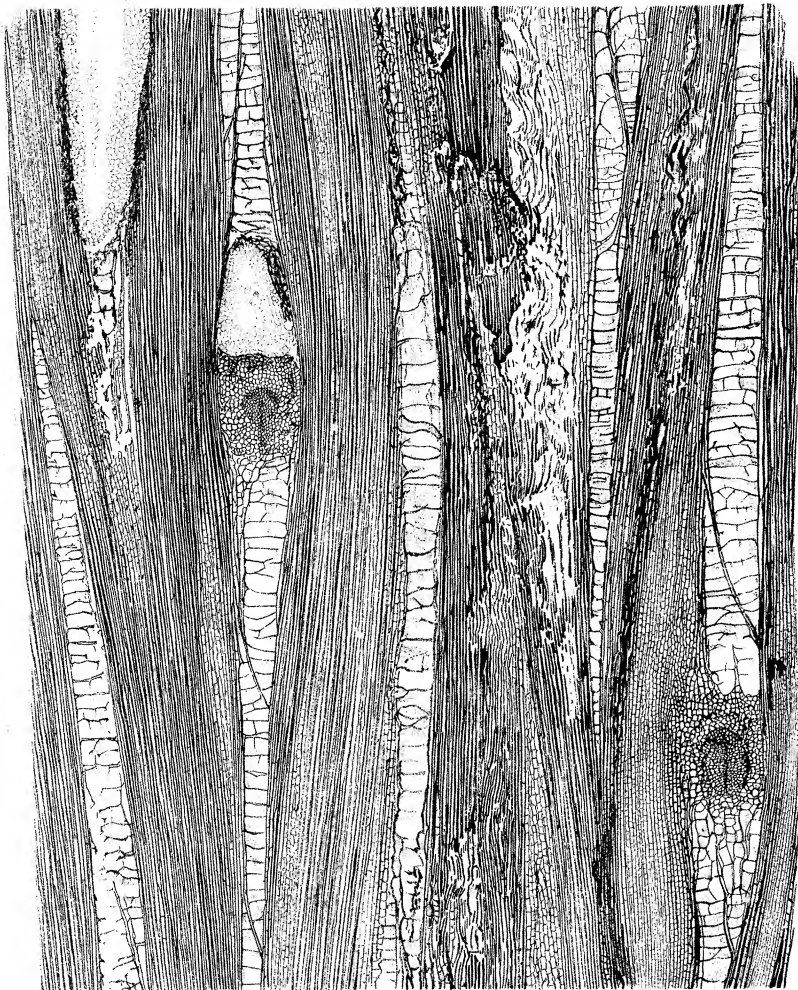




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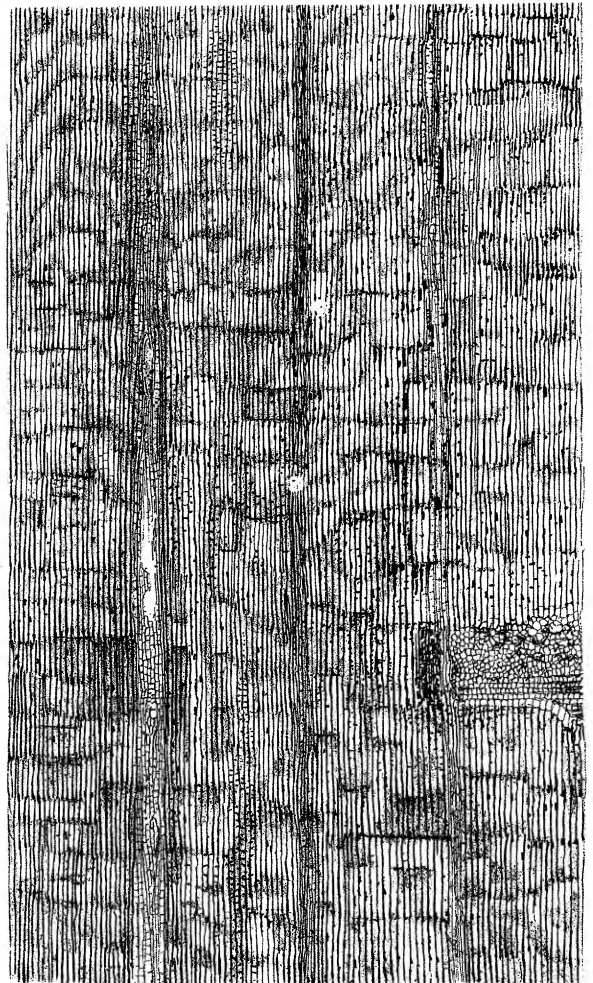


2.



d d' d d'' d'

3.

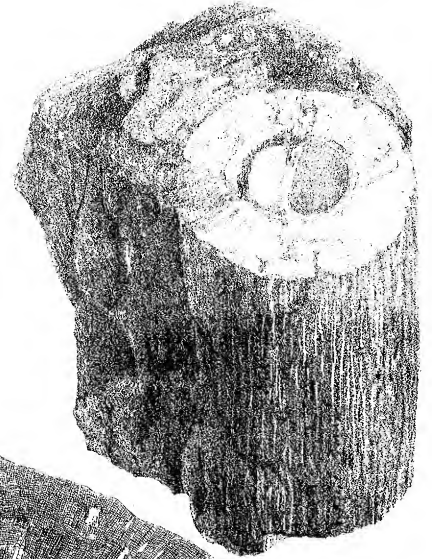
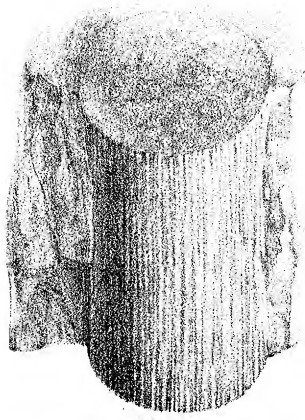
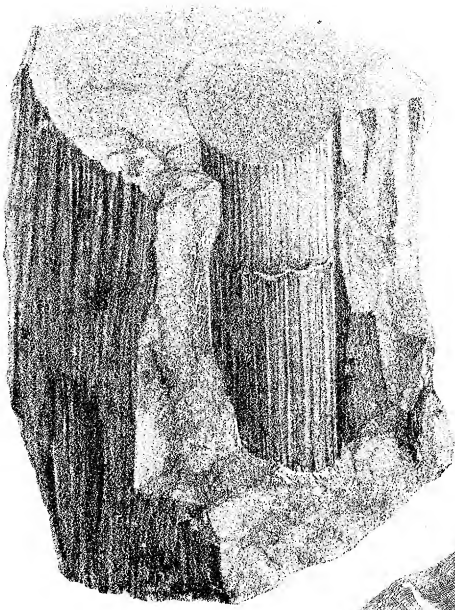


d'' d

1.

2.

4.



5.

6.

3.

